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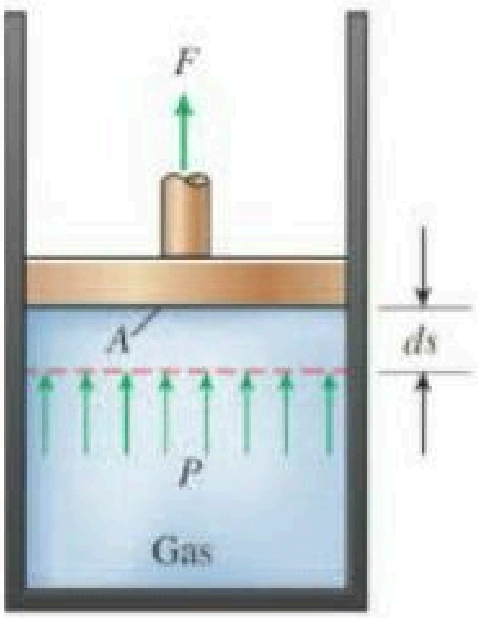

Department of Mechanical and Construction Engineering
Faculty of Engineering and Environment

DESIGN A CYLINDER PISTON PUMP
W22055397

| KB4044 | 29/2/2024

1.1 Coursework Tasks to be Completed by Students

You are asked to design a cylinder piston pump. Your client desires that the pump system be large enough to raise the air pressure from 1 bar to (2+X/2) bar in 10 min at room temperature. The power given to the pump is 100 W. Consider that the air inside the pump behaves as an ideal gas. All your calculations must be based on the Thermodynamic theory. You can use Excel or MATLAB to do your calculations.

Note: The **X** is the last number of your student number. w22055397 would give X=7. Fluid property data can be found online (e.g The Engineering ToolBox).

The tasks you need to perform are the following.

- Identify and discuss the type of physical process that happens during the compression.

Compression is a process under which volume of the system is gradually reduced, pressure and temperature increase where heat transfer may or may not be possible. While in expansion process v with the decrease in pressure and temperature and heat tra possible.

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When subjected to compression, the material will experience some deformation, even if it is undetectable, causing the average relative positions of its atoms and molecules to shift. The distortion may be permanent or can be reversed when the compression forces are removed. In this situation, deformation generates reaction forces that resist compression forces and may finally balance them.

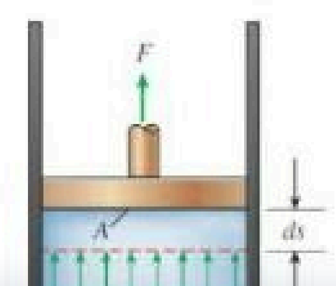


Fig (1) Moving cylinder with force applied

Apart of boundary moves back and forth

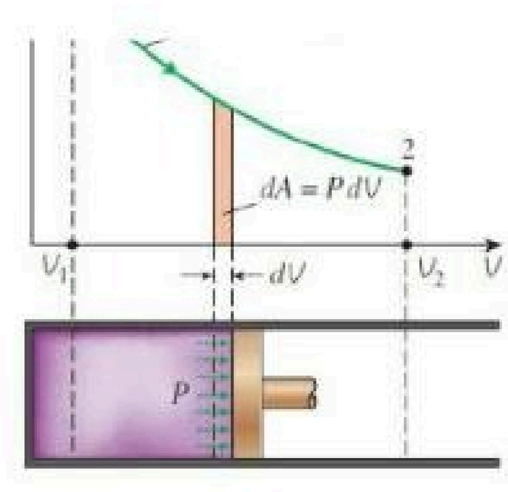
Expansion and compression work are often called moving boundary work or simply boundary work

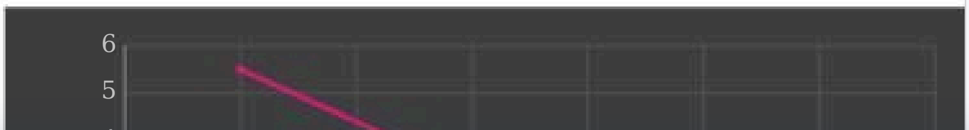
The work associated with real engines or compressor s

The work cannot be exactly determined from a thermodynamic analysis alone:
The piston moves at very high speed
Difficult for the gas to maintain equilibrium
The state through which the system passes cannot be specified
The work is determined by direct measurement
Closely approximately by real engines especially when the piston moves at low velocity
The piston is allowed to move a distance in -a quasi- equilibrium manner

All typical materials will contract.

- Design cylinder piston pump. That involves determining its dimensions, such as volume, diameter, length, and air mass based on thermodynamic equations.





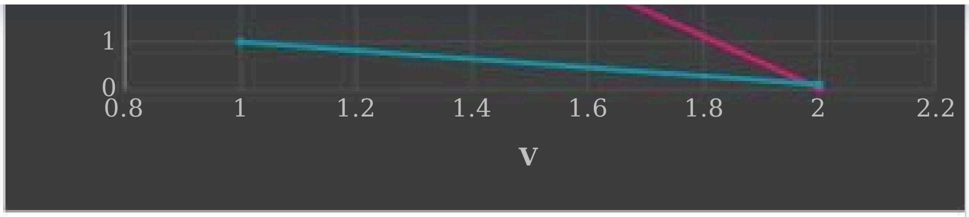


Fig (2) process path between pressure and volume

Solution:

	Power=pressure*Qflow rate/600				
	Q=power*600/ p=	**10.90909091**	lit/ min		
	Q=volume(v)/time(t)=				
volume	volume(v1)=Q* t=	**109.0909091**	lit 3	0.109090909	m3
	in isothermal state P1V1=P2V2				
	V2=P1V1/P2	19.83471074	lit 3	0.019834711	m3
work	w=- P dV	8925.619835	-8.925619835	Kj	
diameter	P*A-Fn=W	BY NEGLECTING FRICTION FORCEFN			
	W=P*A		W=POWER/ TIME	600	6 K
	A=W/P	π(D2/4)	0.06		
	D=	0.276339712 m			
	R=	0.138169856	m		
	Volume=πr2L				
	L=volume /π* r2	1.818181818	m		

m=P1V1/RT1	92	kg

- Provide the change in heat, enthalpy, and internal energy during the compression process. Discuss the results obtained.

The ideal gas law describes the relations between pressure, temperature and volume in an ideal gas

Assumption
The process is reversable
There is no friction

Provide the change in heat			
	V1/T1=V2/T2 T2=V2/ V1*T1	1639	**K**
enthalp y	ΔH =Q=m Cp ΔT	25.3267068 8	kj
and internal energy during the compression process			
	ΔU=ΔH+W=	16.4010870 4	kj

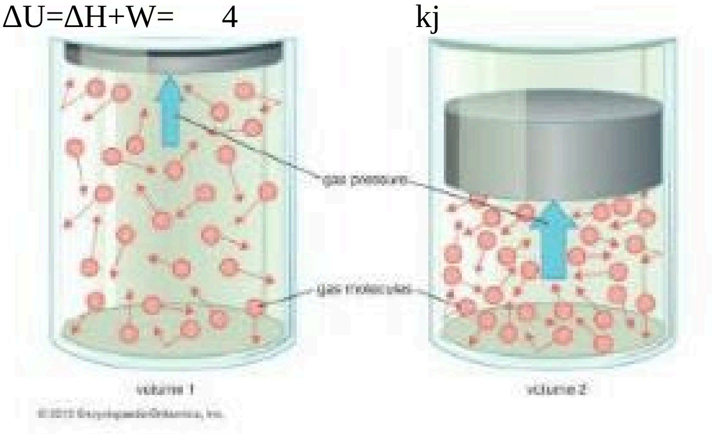


Fig (3) ideal gas law

During the expansion of the stroke of the piston the air increasing in temperature

Is 16.4 KJ it reduced in all system the fluid will change state as a result of work and heat transfer all substances obey an equation of state of one form

- Draw the cylinder piston in SolidWorks or similar software. Indicate every component of the piston.

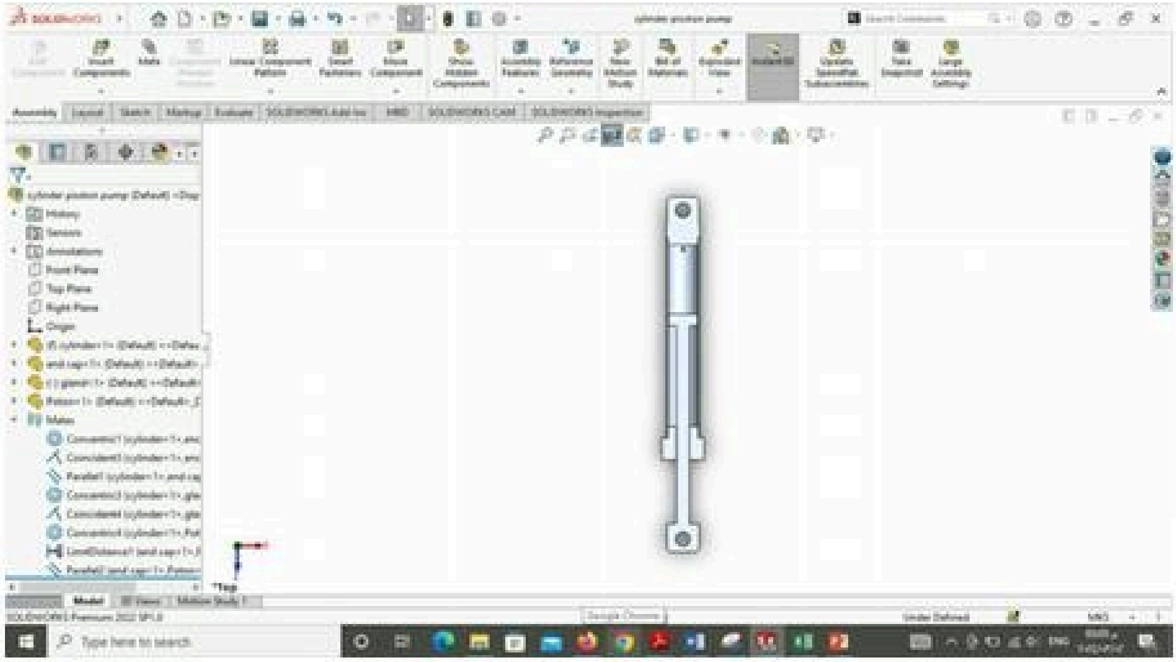
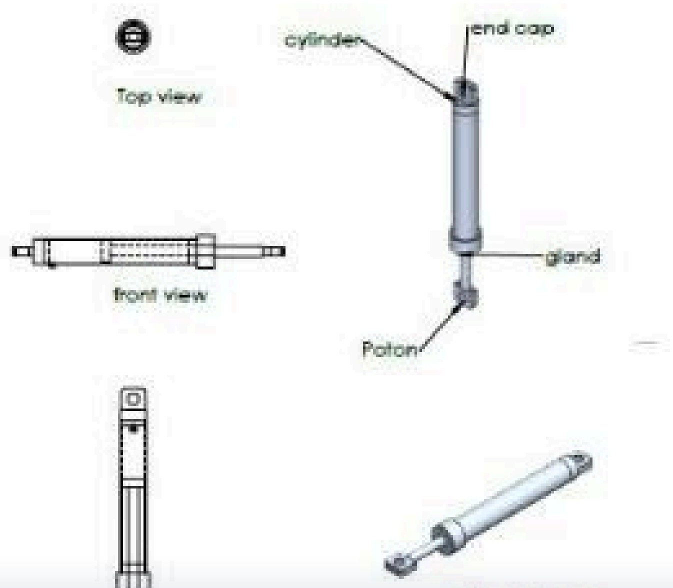
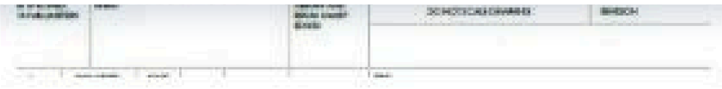


Fig (5) piston in SolidWorks

ITEM NO.	PART NUMBER	QTY.
1	cylinder	1
2	end cap	1
3	gland	1
4	Poton	1



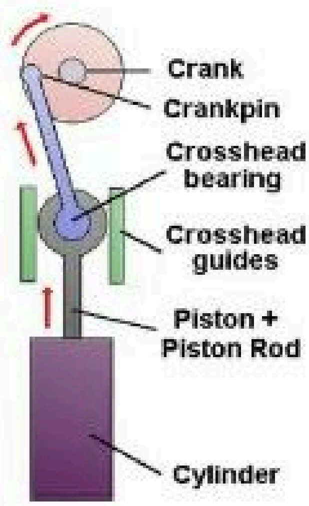


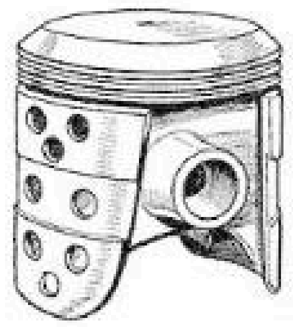
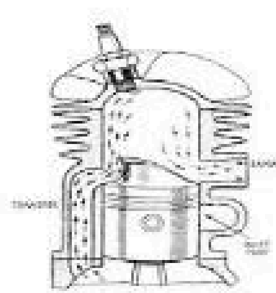
- **a cylinder.**
- **End cap.**
- **Potton.**
- **gland.**

- Describe an engineering application for the piston and add a diagram that integrates it.

Common uses for a piston:

- In the combustion chamber of an IC engine,
- In a hydraulic pump, especially a variable volume one,
- In a hydraulic cylinder, as a ram, or double acting actuator,
- In a steam engine to convert stream to power motion,
- In a syringe to inject medications into patients,
- In self-loading firearms to push the bolt,
- To meter volume of material in a process,
- In an air compressor,
- In an air conditioner to circulate the working fluid,
- In a heat pump.

Types	application	Advantages	Photo
Internal combustion engines	car diesel engines.	The combustion chamber's maximum pressure may reach 20 MPa, and some piston surfaces can achieve temperatures beyond 450 °C. By constructing a unique cooling chamber, piston cooling may be enhanced. Typically, aluminum alloys are cast or forged into pistons. For increased vigor and endurance	
Trunk pistons	diesel engines **marine vessels, power generators, and industrial machinery**	High-speed engines have shifted to using lighter slipper pistons, which have a groove for an oil ring beneath the gudgeon pin and big, double-acting rings between the gudgeon pin and crown.	
Crosshead pistons	Large slow-speed Diesel engines	has a sizable piston rod that extends from the piston downward to essentially create a second piston with a smaller diameter. In addition to carrying the piston rings, the main piston is in charge of gas sealing. The smaller piston serves just as a mechanical reference. double acting: a seal around the piston rod is necessary because steam is supplied to both sides of the piston.	

Slipper pistons	classic car and motorbike racing	minimized in terms of both size and weight. They are reduced to the piston crown in the worst situation. The reduction of the reciprocating mass is the main goal. decrease in the cylinder wall's friction	
Deflector pistons	Two-stroke gasoline engines	In order to stop the incoming mixture from crossing over directly between two ports, Priorities in design include low weight and a high power-to-weight ratio.	
Racing Pistons	Racing engine	piston strength and stiffness are far higher than in a passenger automobile engine. weight is significantly lower in order to reach the high engine RPM required for racing.	

- Propose solutions and/or improvements that could reduce the energy consume for the cylinder piston. Indicate how your client could implement them. Evaluate the reduction on operation cost and carbon

footprint after the improvements have been implanted.

The excessive energy use is caused by Friction between the pipe walls or inside the fluid in motion is the source of these losses. Fluid viscosity also influences the efficiency and dynamics of a system. Physical system elements like pipe fittings or valves may also be to blame.

Energy recovery is a possible if the proper valves and electro-hydraulic components are used to enhance and minimize energy consumption, as previously mentioned. Used in systems with an active load, variable load systems employ it less frequently.

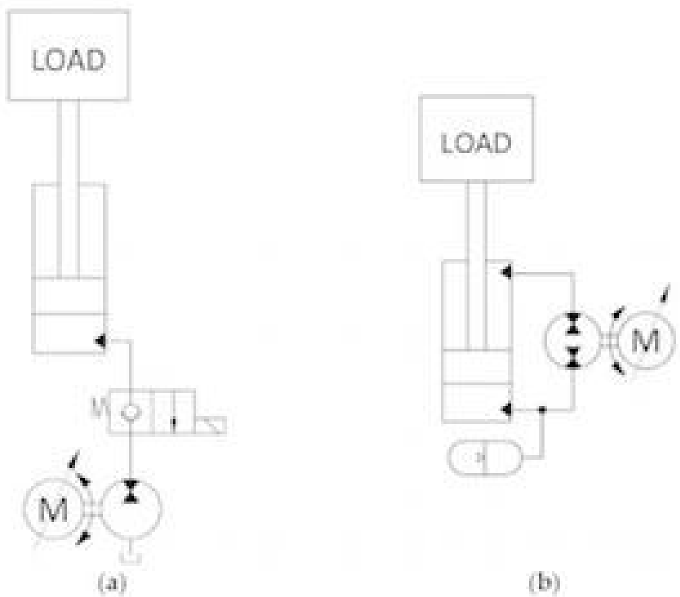


Fig (5) Frequency inverter (FI) application: (**a**) open circuit; (**b**) closed circuit.

Energy recovery is only achievable with two devices: a flywheel and a frequency inverter. When braking a piston rod loaded with active force, a frequency inverter operating in vector mode must have an energy recovery module installed. Despite being a low power and limited lifting capacity machine, the updated drive system may save energy usage by 13%.

The second is the flywheel, an older energy-storage technology that is still in use today because of developments in materials science and bearing technology. In all three of the piston rod loading scenarios, it allows for a decrease in energy consumption and even its recovery.

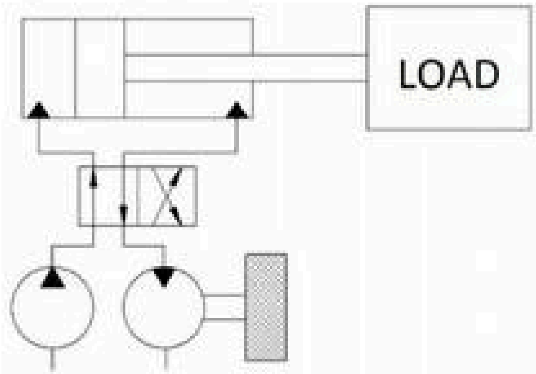


Fig (6) Flywheel (FW) application.

According to the solutions, this is a development that has a lot of potential advantages for industrial uses in both fixed and mobile electrohydraulic systems. This appears to be especially relevant in the context of industry 4.0 and carbon footprint reduction.

Choosing the right approach for systems that place a varied load on the piston rod during a single movement cycle is the most challenging assignment. The decrease of energy consumption and the actual costs of production and maintenance of the hydraulic system are essential criteria in addition to safety considerations.

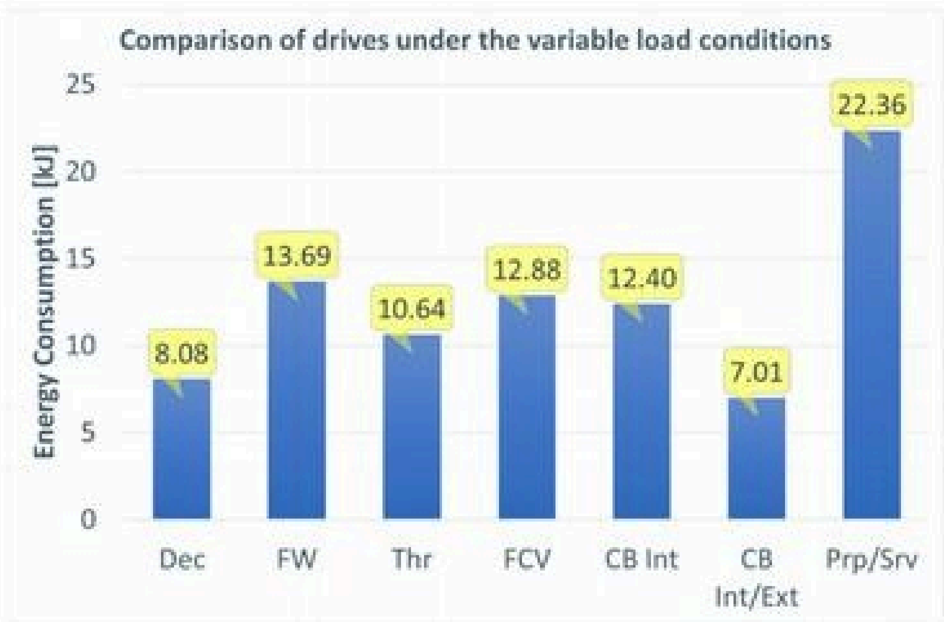


Fig (7)Energy consumption of different drives with double-acting actuator under the variable load.

Conclusions

This article summarizes of design a cylinder piston pump. Your client desires that the pump system be large enough to raise the air pressure from 1 bar to (2+X/2) bar in 10 min and the important points for the design the physical process of the cylinder piston pump is One form of mechanical work frequently encountered in practice associated with expansion and compression of gas in a piston cylinder device

The ideal gas law describes the relations between pressure, temperature and volume in an ideal gas

During the expansion of the stroke of the piston the air increasing in temperature by 1341 due to the raise the air pressure from 1 bar to 5.5 bar also the change in enthalpy of air during expansion is 25.3 KJ and internal energy during the compression process Is 16.4 KJ it reduced in all system the fluid will change state as a result of work and heat transfer all substances obey an equation of state of one form

Energy recovery is a possibility when proper valves and electro-hydraulic components are used to enhance and minimize energy usage, as detailed above. It is commonly utilized in systems with an active load, but less so with a changeable load.

Reference:

1- https://en.wikipedia.org/wiki/Piston

2- Energy Efficiency and Limitations of the Methods of Controlling the Hydraulic Cylinder Piston Rod under Various Load Conditions -Institute of Machine Tools and Production Engineering, Lodz University of Technology, Stefanowskiego 1/15 Street, 90-924 Lodz, Poland.